

## **SPECIFICATION AMENDMENTS**

On page 1, above line 1, insert--Priority Claim

---The present application is a 35 U.S.C.371 national stage filing of PCT/EP2003/027995 filed September 5,, 2003 claiming priority of United States provisional application 60/408,427 filed September 5, 2002, hereby incorporated by reference.---

Paragraph at line 22 of page 1, ending at line 17 of page 2 has been amended as follows:

--Electricity can be produced in fuel cells using pure hydrogen. Hydrogen production is commercially proven, but expensive. One method of producing hydrogen is steam methane reforming where hydrocarbons and water are reacted to form CO and H<sub>2</sub>, followed by a separate water-gas-shift reaction where CO is reacted with H<sub>2</sub>O to form CO<sub>2</sub> and H<sub>2</sub>. The commercial application of these reactions in many refineries commonly involves a series of reactors including a steam reforming reactor, and several post reactors to address the production of CO in the reformer. The post reactors include a high temperature shift reactor, a low temperature shift reactor, and a CO<sub>2</sub> absorber separator. Water and CO<sub>2</sub> separation is necessary to achieve pure hydrogen. The reforming reactor is run at high pressure to avoid hydrogen recompression downstream. The pressure lowers the equilibrium conversion since reforming produces a positive net mole change. The steam reforming reaction is very endothermic; and the shift reaction is also exothermic. The conventional steam reforming reactors are operated above 900°C to push the equilibrium toward complete formation of CO and H<sub>2</sub>. The high temperature causes severe corrosion and stress problems on the equipment. Steam reforming reactors are generally large to accomplish economies of scale. In addition, the typical operation of the shift reactor at a lower temperature than the reforming reactor makes it impractical to combine these two chemical reactions in one reactor. Furthermore, designs currently known do not lend themselves to being scaled down to a smaller size or to making it possible to efficiently control the temperature at various points.--

Paragraph at line 18 of page 5, ending at line 10 of page 6, has been amended as follows:

-- The present invention provides a new process and apparatus for steam reforming of any vaporizable hydrocarbon to produce  $H_2$  and  $CO_2$ , with minimal CO as end-product, and having minimum concentration of CO in the  $H_2$  stream, said process being accomplished in one reactor, at lower temperatures than those used in conventional steam methane reforming reactors, constantly removing pure hydrogen, and using as a heat source flameless distributed combustion which provides great improvements in heat exchange efficiency and load-following capabilities to drive the steam reforming reaction. Similar efficiency and load-following is simply not possible with conventional firebox steam reformer furnace designs and multi-reactor shift units. The flameless distributed combustion heat source makes it possible to transfer between 90 and 95% of the heat to the reacting fluids. In another embodiment, the invention is also a zero emission hybrid power system wherein the produced hydrogen is used to power a high-drogen-is-used-to-power-a-high-pressure internally or externally manifolded molten carbonate fuel cell. The system is capable of achieving 71% or greater efficiency in the conversion of fuel to electricity. In addition, the design of this flameless distributed combustion - membrane steam reforming reactor (FDC-MSR) fueled hybrid system makes it possible to capture high concentrations of  $CO_2$  for sequestration or use in other processes. Finally, the design of the system can be scaled down to a mobile, lightweight unit.--

Paragraph at line 4 of page 19 has been amended as follows:

-- With the FDC-MSR process and apparatus of the present invention it is possible to use O: C ratios as low as 2.8, down to 2.6, without coking problems, with the minimum O: C ratio being about 2:1. This results in lower energy costs if methane is used as the feed in the present invention, since lower steam to methane ratios can be used thus requiring less energy to vaporize water. Because of the ability to operate at lower O:C ratios, it is also possible to use heavier, less expensive feeds in the FDC-MSR reactor of the present invention than can be used in conventional steam methane reformers.--

Paragraph at line 25 of page 38, ending at line 27 of page 39, has been amended as follows:

-- Figure 12 is a top cross-section view of the shell of the multi-tubular, FDC heated, axial flow, membrane reactor shown in Figure 11. In the embodiment shown multiple membrane tubes 71 and multiple FDC tubes 72 are dispersed in reforming catalyst bed 70. The multiple FDC tubes employed in this embodiment are "closed ended" FDC tubes as discussed above in connection with Figure 11. The membrane tubes are equipped with an outer sweep gas feed tube and an inner hydrogen, sweep gas return tube as discussed in connection with Figure 11. A typical reactor of the type shown in this Figure 12 may comprise, for example, 19 FDC tubes of 5.5" OD and 90 membrane tubes of 2" OD enclosed in a shell of 3.5 ft diameter containing catalyst in the void spaces. Other shell sizes and numbers of tubes can be suitably employed depending on the capacity needed. The design parameter which is of ~~outmost~~ utmost importance is the optimum gap between the membrane and the FDC tubes. If a high gap is assumed, then heat transfer limitations occur since the flow of ~~enthalpy~~ heat from FDC to the reforming reaction is slow. The membranes may not operate isothermally and cold spots may develop, thus reducing the reactor efficiency. If a small gap is assumed, then there may be problems with insufficient catalyst penetration in the gap, overheating of the membrane, or even touching of the hot FDC tube with the membrane in conditions where the tubes are not perfectly straight. A narrow gap limitation will make reactor fabrication more expensive, since clearances are hard to achieve. Thus, an intermediate gap is more preferable. As a particular non-limiting example, the gap between the membrane and the FDC tubes is from about ¼ inch (about 0.64 cm) to about 2 inches (about 5.08 cm), particularly from about ½ inch (about 1.27 cm) to about 1 inch (about 2.54 cm). The gap between the membrane tubes may be from about ¼ inch to about 2 inches, particularly from about ½ inch to about 1 inch and this has to be also optimized. The hydrogen-permeable membrane tube has a ratio of length to diameter of less than about 500.--